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Indian Standard

GENERAL CONSIDERATIONS FOR TELECOMMUNICATION SERVICES FOR ELECTRIC POWER SYSTEMS

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BUREAU OF INDIAN STANDARDS
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Power Line Carrier Systems and Associated Telecontrol Equipment Sectional Committee, LTD 25

NATIONAL FOREWORD

This Indian Standard which is identical with IEC Pub 1085 (1992) 'General considerations for telecommunication services for electric power systems', issued by the International Electrotechnical Commission (IEC), was adopted by the Bureau of Indian Standards on the recommendation of Power Line Carrier Systems and Associated Telecontrol Equipment Sectional Committee, LTD 25 and approval of the Electronics and Telecommunication Division Council.

The text of the IEC standard has been approved as suitable for publication as Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

CROSS REFERENCES

In this Indian Standard, the following International Standards are referred to. Read in their respective places the following:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 870-1 : Telecontrol equipment and systems — Part 1 : General considerations	IS 12746 (Part 1/Sec 1) : 1996 Telecontrol equipment and systems — Part 1 General considerations (*under preparation*)	Identical
IEC 870-2 : Telecontrol equipment and systems — Part 2 : Operating considerations	IS 12746 (Part 2) : 1989 Telecontrol equipment and systems: Part 2 Environmental conditions and power supplies	Identical
IEC 870-3 (1989) Telecontrol equipment and systems — Part 3 : Interfaces (Electrical characteristics)	IS 12746 (Part 3) : 1995 Telecontrol equipment and systems : Part 3 Interfaces (electrical characteristics)	Identical
IEC 870-4 (1990) Telecontrol equipment and systems — Part 4 : Performance requirements	IS 12746 (Part 4) : 1993 Telecontrol equipment and systems : Part 4 Performance requirements	Identical
IEC 870-5 Telecontrol equipment and systems — Part 5 : Transmission protocols	IS 12746 (Part 5) : 1993 Telecontrol equipment and systems: Part 5 Transmission protocols	Identical
IEC 50 (371) (1984) International electrotechnical vocabulary (IEV) — Chapter 371:Telecontrol	IS 1885 (Part 50) : 1985 Electrotechnical vocabulary: Part 50 Telecontrol	Technically Equivalent
IEC 834-1 (1988) Performance and testing of teleprotection equipment of power systems — Part 1 : Narrow-band command systems	IS 13968 (Part 1/Sec 1-5) : 1994 Performance and testing of teleprotection equipment of power systems: Part 1 narrow-band command systems	Technically Equivalent
IEC 353 (1989) Line traps for a.c. power systems	IS 8792 : 1995 Line traps for Ac power systems — Specification (*first revision*) IS 8793 : 1995 Line traps for AC power systems — Methods of test (*first revision*)	Technically Equivalent Technically Equivalent

(Continued on third cover)

IS 14392 : 1996
IEC 1085 (1992)

Indian Standard

GENERAL CONSIDERATIONS FOR TELECOMMUNICATION SERVICES FOR ELECTRIC POWER SYSTEMS

1 Scope

This Technical Report is intended to give an overview of the specific problems and requirements for electric power utility telecommunication systems.

2 Normative references to related international standards and reports

The following standards contains provisions which, through reference in this text, constitute provisions of this Technical Report. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Technical Report are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

There are many international standards and reports covering the topics considered in this report and the following subclauses detail those relevant to each aspect.

2.1 *General*

Guide for planning of power systems telecommunication systems (1985).*

ANSI/IEEE STD 367 - 1987: *IEEE recommended practises for determining the electric power station ground potential rise and induced voltage from a power fault.*

2.2 *Telecontrol*

In the area of telecontrol the IEC Technical Committee No. 57 is in the process of producing a very useful publication. This publication, IEC 870, consists of six parts as follows:

IEC 870-1: *Telecontrol equipment and systems - Part 1: General considerations.*

IEC 870-2: *Telecontrol equipment and systems - Part 2: Operating considerations.*

IEC 870-3: 1989, *Telecontrol equipment and systems - Part 3: Interfaces (electrical characteristics).*

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* Published by CIGRE Working Group 04 of Study Committee 35.

IEC 870-4: 1990, *Telecontrol equipment and systems - Part 4: Performance requirements.*

IEC 870-5: *Telecontrol equipment and systems - Part 5: Transmission protocols.*

IEC 870-6: *Telecontrol equipment and systems - Part 6: Telecontrol protocols compatible with ISO and CCITT standards* (under consideration).

The following two documents, published by the IEC and IEEE respectively, are also very useful:

IEC 50(371): 1984, *International Electrotechnical Vocabulary (IEV) - Chapter 371: Telecontrol.*

IEEE P 565/D3 5-27-77: *Manual of automatic and supervisory station control data organisation.*

2.3 *Teleprotection*

IEC Technical Committee No. 57 has produced the following standards on performance and testing of teleprotection equipment:

IEC 834-1: 1988, *Performance and testing of teleprotection equipment of power systems - Part 1: Narrow-band command systems.*

IEC 834-2: *Performance and testing of teleprotection equipment of power systems - Part 2: Analogue comparison systems* (in preparation).

2.4 *Power line carrier (PLC)*

IEC Technical Committee No. 57 has produced the following standards:

IEC 353: 1989, *Line traps for a.c. power systems.*

IEC 481: 1974, *Coupling devices for power line carrier systems.*

IEC 495: 1974, *Recommended values for characteristic input and output quantities of single sideband power line carrier terminals.*

IEC 663: 1980, *Planning of (single sideband) power line carrier systems.*

2.5 *Radio*

Recommendations and reports of the CCIR, XVIth Plenary Assembly, 1986, Volume IX - Part 1: *Fixed service using radio-relay systems.*

Recommendations and reports of the CCIR, XVIth Plenary Assembly, 1986, Volume VIII - Parts 1-3: *Mobile services.*

2.6 *CCITT*

- FDM:
CCITT Blue Book (1988) - Volume III - Fascicle III-2: *International analogue carrier systems. Transmission media characteristics.*
- TDM:
CCITT Blue Book (1988) - Volume III - Fascicle III-3: *Digital Networks. Transmission system and multiplexing equipment*
- CCITT Blue Book (1988) - Volume VIII - Fascicle VIII-7: *Data communication networks. Message handling systems. Recommendations X.400 - X.420.*

2.7 *Electro-magnetic compatibility*

Immunity tests (IEC 801 and IEC 1 000 series).

3 General

An electric power system consists of a number of power stations (thermal and hydro) located in different parts of a country supplying electric power via a transmission and distribution network to feed loads which are spread across the territory and are remote from the power stations. The transmission network connects the power stations to substations where switching and transformation to lower voltages takes place and from where loads, domestic and industrial are supplied via a distribution network.

An electric power system is frequently referred to as an electrical public utility. In order to administer and operate the utility, in addition to the power stations, transmission and distribution substations, a number of other units can be identified (see figure 1). These are:

- a headquarters to run the utility;
- one or more control centres to determine which power stations should operate and how the transmission and distribution network shall be used;
- one or more maintenance centres;
- one or more computing centres for support of the control centre(s) and for support of headquarters.

These units obviously cannot work in isolation and hence require telecommunication services. The following subclauses in clause 3 identify the functions to be executed and the consequent telecommunication services needed to satisfy the functions.

3.1 *Functions*

3.1.1 *Administrative telephony* (see figure 2)

At the most basic level headquarters will need to communicate with all locations within the utility by voice, that is telephony, and may also wish to use telex and facsimile services and, increasingly, electronic mail services. The locations will also wish to communicate with one another.

Locations will also need telephone connections to outside of the utility, that is via the public switched telephone network (PSTN) and this may again include telex and facsimile services.

3.1.2 *Operational telephony* (see figure 3)

The control centre(s) requires rapid and simple telephone access to the power stations, substations and the maintenance centre(s). Telephone access is also required to neighbouring power utilities for the purpose of scheduling the interchange of electrical power.

3.1.3 *Telecontrol (SCADA)* (see figure 4)

In order that the control centre can carry out its function it needs to be provided with all the information about the power system, namely status positions (i.e. monitored information such as circuit-breakers, isolators, alarms), measurands, integrated totals, etc., from the power stations (thermal and hydro) and substations which are of course remote from the control centre. It is also necessary to control electrical and hydraulic plant. If load frequency control (LFC – also known as Automatic Generation Control) is used then remote control of the turbine-alternators at the power stations will also be required.

In the case of hydro-electric power stations hydraulic data, such as rainfall and water level, also needs to be returned to the control centre.

At the control centre(s) this information is used to drive a man-machine interface consisting of mimic diagrams and visual display units (VDU's).

The system used to handle all these aspects is known as a telecontrol system or SCADA (Supervisory Control and Data Acquisition) system.

3.1.4 *Load management* (see figure 5)

An electrical power utility may wish to improve its system load factor throughout the day by offering incentives to customers to utilise electric power at particular periods of the day. This function is known as load management and is achieved by the remote switching in or out of loads. Load management may be under the control of the control centre or it may be an automatic feature such as when it is used for the control of street lighting.

3.1.5 *Teleprotection* (see figure 6)

Where the occurrence of an incident on the power system requires protective action at another location teleprotection is used.

3.1.6 *Mobile radio* (see figure 7)

In support of the operation of the power system, under the control of the control centre(s), there will be a maintenance organisation with one or more locations in the territory covered by the utility. These maintenance centres will have mobile crews who can be reached either in their vehicles or directly on a "walkie-talkie" basis. For this, mobile radio is used typically in the VHF (70-165 MHz) and UHF (400-470 MHz) bands.

3.1.7 *Computing traffic* (see figure 8)

In modern utilities it is usual to have at least one main-frame computer with, in addition, smaller mini-computers located elsewhere connected to the main-frame.

The main-frame may be used by the control centre for off-line planning studies. It may also be used for administrative services such as wages and billing.

3.2 *Telecommunication services*

3.2.1 *Administrative telephony*

To satisfy the administrative needs of the utility (3.1.1) a private network is usually provided, which makes use of suitable communication media (see 5.1) together with private automatic exchanges and, if the network is large enough, with transit exchanges.

For connection to the public network, public exchange lines are usually provided to all locations requiring the service.

3.2.2 *Operational telephony*

To satisfy the operational telephony needs (3.1.2) a special purpose telephone system is usually provided with key calling of a limited repertoire of extensions and, where such a system is shared with the administrative private network (3.2.1), a priority feature which ensures that the control engineer always has access to the desired extension.

3.2.3 *Telecontrol*

Telecontrol systems (3.1.3) consist of equipment at the control centre(s), sometimes called master station(s), connected via suitable communication media to outstations located in the power stations (thermal and hydro) and substations. These outstations are interfaced to the relevant electrical parameters and receive commands and return information rapidly, accurately and continuously.

At the control centre(s) the equipment consists of mini-computers working with the outstations and animating the mimic diagrams and VDU's.

3.2.4 *Load management*

Where load management is applied to domestic or industrial loads by remote teleswitching, requiring access to a large number of consumers, one way radio communication may be quite sufficient, in which case there is one central radio transmitter and many radio receivers.

On the other hand where control of street lighting or control of domestic electric water heating is required, mains borne signalling may be used (also known as ripple control).

3.2.5 *Teleprotection*

Teleprotection systems provide a means of transmitting protection information or protection commands from one location to another via suitable communication media. Fast, reliable and error free operation is essential for such services.

3.2.6 *Mobile radio*

For mobile radio systems with a defined area to be covered there will typically be one or more base stations connected to the maintenance centre by suitable communication media. The vehicles will be equiped with a radio transmitter/receiver with access to one or more radio channels in the VHF or UHF band. Hand portables may also be used in this application and where the service distances are small, UHF is usually preferred. Where vehicles are used, some may be equipped with a text message capability.

3.2.7 *Computing traffic*

Computing traffic usually consists of large amounts of data transferred either to or from or both ways into the main-frame. There may also be a large amount of interactive traffic.

Such traffic requires error protection as well as high speed signalling, typically 2,4 kbits/s, 9,6 kbits/s, or 64 kbits/s and even higher. Suitable communication media are required for such traffic.

3.2.8 *Other services*

Telex, facsimile and electronic mail traffic usually consists of small amounts of data transferred between operational and administration centres. Signalling speeds range from 50 bits/s for telex to 2,4 kbits/s for facsimile and electronic mail. No error protection is usually provided for telex and facsimile; error protection is provided however for electronic mail systems based on the CCITT Recommendation X.400. Suitable communication media are needed for all such traffic. Message switching facilities for telex and electronic mail bring extra benefits at reasonable cost.

3.2.9 *Public address system (PA System)*

Public address systems are widely used by electrical power utilities for administration, safety (fire, radiation, evacuation) and operational broadcasts. For internal power station operational requirements where only one way communication is necessary, a PA system provides a very convenient means of communicating to a group of people collectively.

3.2.10 *Network management*

It is usual for modern utilities to employ network management techniques for administering the telecommunications network. A centrally-located management centre collects traffic and transmission quality and failure data remotely and is capable of making software changes to accomplish the most reliable routing of traffic.

3.2.11 *Power supplies*

To support the aforementioned telecommunication services, power supplies are required which should be engineered to match the desired security and reliability. Thus all supplies should be backed by electrical storage, for example batteries, so that the supply continues to be available during power system failures.

3.3 *Summary*

An electrical utility may elect to provide its own entire telecommunication services or a portion of them for the following reasons:

i) The essential service provided by an electrical utility requires integrity and availability of communication better than a PTT could normally offer.

ii) A public telecommunications operator may not be prepared to provide all the facilities required in a cost effective way.

Regardless of whether or not the electrical utility or the PTT provides the service, isolation problems and general electro-magnetic compatibility (EMC) at substations and power stations should be taken care of in providing safe, secure and reliable service.

4 Service requirements

4.1 *Telecommunication and operational services*

4.1.1 *Administrative telephony*

In common with all industrial and commercial organizations an electrical public utility needs a suitable service of telephony. However, the requirements for such a service are more demanding than for many other organisations because the telephony facilities may strongly influence the image of the utility to the electricity supply users.

Administrative telephony should be able to service complaints from the public, demand for electrical supply from the public, as well as work organization, fuel provision and fuel movement within the organization.

4.1.2 *Operational telephony*

Due to the importance of the voice communication needs of staff in charge of generation, transmission and distribution of electrical power, there is a need for an operational telephony service.

In an electrical utility operational telephony is the most important working tool. Together with telecontrol, it is used for managing and supervising the power network but operational telephony has to be available even when the telecontrol system fails.

The traffic offered by the operators is not high; nevertheless operational telephony requires features that cannot be provided except by means of specially dedicated networks.

In addition to the very high reliability and availability required, an operational telephone network shall provide the following facilities:

- very rapid access;
- priority subscribers, with call intrusion and forcing down ("knock-down") facilities;
- conference facilities;
- alternative routing of calls;
- automatic re-routing of calls;
- hunting for free trunks in groups;
- non-blocking transit switching;
- closed numbering scheme;
- barring certain extensions from calling subscribers outside predetermined exchange areas.

It is also desirable to have indication of the origin of the incoming call.

In order to provide the above facilities, the operational telephone network should be based on special exchanges with a more sophisticated signalling system than usual.

A priority call, for example, has to be able to transfer the information about the priority throughout the network by means of a signalling system which enables the exchanges to perform in the manner required for this type of call, i.e. intrude on and/or disconnect a telephone conversation of lower status if free trunks or a subscriber cannot be found.

Similarly, features such as conference and re-routing of calls require the transfer of suitable information about the type and status of calls and of the trunk channels interconnecting the transit exchanges. Such features should be provided either for analogue or digital interconnection channels whether only a single channel is used or many channels.

As the calls in an operational network may be of an extremely urgent nature, the signalling system is required to be very fast and reliable, so that the time spent in setting up the call is kept to a minimum.

The attraction of a closed numbering scheme is that to reach a certain subscriber the same number is dialled irrespective of from which exchange within the network the call is placed.

To operate a network-wide closed numbering scheme and automatic alternative re-routing requires digital store and forward facilities and stored programme control (SPC) of the exchanges.

Operational staff at control centres should have the capability of maximum priority and intrusion ability to produce a grade of service of 100 % (i.e. availability of 100 %) with zero (or minimum) waiting time.

In order to ease the operation and speed up the calling procedures, such staff should be provided with equipment enabling calls to be set up to the required destination by simply pressing a key or button (one key or button) per destination.

The fulfilment of the above functional requirements can be easily accomplished by using dedicated meshed networks, which are the most suitable solution for medium and large size power networks. In such cases the operational telephone network can also be profitably used for internal administrative communications, at least as a back-up system.

For smaller networks with low traffic density or as a back-up facility to the dispatching and control operators, party line systems may be a suitable alternative.

It is clear from the foregoing that the transit exchanges and the other equipment used in the operational telephone networks of electrical utilities have to be quite special and different from those used in public networks.

4.1.3 *Telecontrol*

Telecontrol at its most basic concept means controlling a power station or substation remotely just as if the operator was actually at the station. One of the benefits is a noticeable saving in manpower since one operator can control several stations, thus reducing operating costs.

Telecontrol provides for data acquisition from the remote stations towards the control centre and in the reverse direction commands from the control centre to the remote stations.

Telecontrol does not however mean only telecommand for changing the state of circuit breakers and isolators (disconnectors), or setting some of the operational conditions of some of the equipment. It also means supervision of the overall state of the electrical network as a unique process to ensure its security, reliability, availability, and economy in electrical energy provision. To be effective, this requires the telecontrol system to carry out the functions of state estimation, detection of bad power system data, etc.

The power system functions that a telecontrol system has to satisfy are listed in the following table 1. The consequent operational functions to achieve these are summarised in table 2. The term energy management system (EMS) is frequently used to embrace all such aspects.

Except in very small electrical networks, the telecontrol functions are usually organised in an hierarchical structure, as shown in figure 9.

At the highest level a telecontrol system can consist of a number of interconnected control centres serviced preferably by a common meshed telecommunication network. The telecontrol system may span more than one power administrative region at control centres and thus the authority over the telecontrol system itself does not necessarily coincide with any particular power system authority.

In most cases the main control centre (MCC) will not execute commands in real time via the telecontrol system but operates via the lower level centres by telephone instruction. Nevertheless, the main control centre will provide overall supervision of the total system and may well schedule the operation of the power stations.

At the level of Regional Control Centre (RCC) actual LFC operations as well as execution of commands may be performed. The RCC is also responsible for the next lower level of operation (District Control Centres), that execute commands after instruction by or agreement with their RCC.

The security, reliability and availability of the electrical power system requires that the telecontrol functions are fast even in updating the telemeasurements and should be of the highest security and reliability. Consistency of information between the measurements and status information is essential for satisfactory operation, especially in times of power system faults. Response times should be short particularly during power system faults when the amount of information to be returned will be very large.

Security is the probability that unwanted or incorrect commands do not occur, while reliability is the probability that a command is not missed and is correctly executed. Similarly the telemetering functions have to be highly reliable, secure and accurate.

All of the foregoing result in the following requirements:

- fast and predictable response times;
- use of suitable transmission protocols and coding for operational data transmission;
- high quality communication media;
- high reliability communication network;
- high availability communication networks both long term (equipment failure) and short term (noise, propagation, interferences).

The transmission capacity of the communication links should match the need to keep the overall response times small consistent with providing the right amount of error protection. Modern power system operation requires that the updating time of the information reaching the MCC is less than a few seconds. Taking into account the amount of information coming from the remote stations, the data throughput can be typically 200 bits/s to 2 400 bits/s between outstations and DCC, typically 2 400 bits/s to 9 600 bits/s between DCC and RCC, and typically 9 600 bits/s to 48 000 bits/s between RCC and MCC.

The data throughput figures are likely to increase with the introduction of the next generation of telecontrol systems which tend to require much shorter response times and higher throughputs in order to enhance the automatic computer-based system control functions and thus improve the security, reliability and availability of the service provided by the utility.

Significant developments in the use of expert systems at the different levels of telecontrol systems are currently underway. Among other things, these may lead to a potential reduction in the quantities of a real-time data transmitted as a result of local automatic alarm analysis in the event of a sudden increase in data.

The overall target availability for the telecommunication links of the primary network (RCC to MCC) should be better than 99,99 %, whereas lower values may be tolerated in the secondary networks where the availability should be better than 99,9 %.

Regarding the telecommunication network configuration, the required long-term availability imposes a need for redundant routing of signals on fully independent paths. This can readily be achieved by mesh configurations.

Redundant routing itself is not sufficient to ensure the required availability in the short term if there are any common mode failures that can affect both paths. Full redundancy means separate entries into a building from separate routes.

Notwithstanding such separation, each communication path should be of sufficiently high quality and high availability to achieve the required availability in the short term when one of the paths is out of service.

A further consideration is the need for flexibility should a DCC, RCC or even an MCC fail.

Table 1 - Power system functions
(to be satisfied by telecontrol)

Network state determination	Topology determination and state estimation. Network equivalence.
Network analysis	Load flow calculations. Short-circuit calculations. Contingency evaluation. Security monitoring.
Thermal power production	Trend monitoring. Set value. Operation reports/production.
Hydro power production	Calculation of water flow. Supervision of legal obligations (levels, flows, etc.). Trend monitoring. Set value. Control signals to local regulating equipment. Operation reports/production.
Network and generation control	Load shedding. Load-frequency control and economic energy management. Load forecast. Unit commitment.
Specific telecontrol system functions	Non-current tagging of measurands.* Non-current tagging of monitored information.*
Post mortem analysis	Post mortem review. Reports of power system disturbances for immediate disturbance analysis. Reports of power system disturbances for subsequent disturbance analysis.
Statistical value processing	General. Statistical value generation. Storage of statistics. Checking of statistical data. Correction/complementing.
Preparation of statistical reports	General Operation reports, power grids. Load prediction (long term).
Training	Training simulator.

* I.E. indication that measurands and/or monitored information are not being updated, and hence are "non-current".

Table 2 - Telecontrol functions

Telemetering	Acquisition of variable quantities. Scaling to engineering units. Calculation of composite values. Override marking. Manual input values.
Teleindication	Acquisition of state information and signals. Time tagging of data. Calculation of composite values. Override marking of indications. Manual inputting of indications.
Telecounting	Acquisition of integrated variable states. Scaling to engineering units. Override marking. Manual inputting.
Telecommand **Teleswitching**	Issuing of commands for change of state (discrete).
Teleregulation **Telereadjusting**	Issuing of regulation information (variable). Blocking.
Monitoring of limits	Monitoring of telemetered quantities against limits. Monitoring of telemetered quantities against forbidden zones. Inputting of limit values.
Event processing and alarming	Classification of events in the power system. Alarm acknowledgment. Alarm clearance. Alarm blocking. Alarm delaying.

4.1.4 *Load management*

To improve the system load characteristic electrical utilities with large power networks sometimes offer enhanced tariffs to consumers who are prepared to restrict their load demands at certain times of the day, e.g. off-peak power.

This gives rise to a requirement for the remote control of tariff meters and the switching of non-essential supplies like water heating loads. This facility requires relatively few commands at infrequent intervals, although there may be a very large number of terminal receivers spread over wide geographic areas and high reliability is needed if security is involved. In addition, this signalling is usually only required in the outwards direction, as there are no revertive or check-back signals in the reverse direction.

As a separate issue, load control and switching may be essential when particular situations require load relief in order to avoid non-secure electrical network operation or black-outs.

Load management is most effective with the biggest medium voltage (MV) or high voltage (HV) users, who offer the largest loads. The techniques first applied for load management employed superimposition of low level audio frequencies on the network power frequency and this is known as ripple control and is still in use. Today it is recognised that the load control schemes are an integral part of the much larger overall telecontrol and telecommunication problem and other techniques using normal telecommunication media are used for the effective load management when it involves high-load users and conditions of shortage of power are possible.

In the case of large power users it may be desirable to implement systems allowing transmission in both directions that permit return of remote meter reading operations as well as other customer data such as number and duration of power supply failures.

In recent years increasing interest has been shown in the provision of load management systems using radio telecommunication techniques, resorting to broadcasting radio system for one-way operation or to private or dedicated networks in the case of two-way systems.

4.1.5 *Teleprotection*

Of necessity teleprotection is treated in a different way to the telecontrol function. This is because teleprotection requires communication between points on a power network, whereas telecontrol requires communication radially from the control centre.

Teleprotection enables discriminative or coordinated operation of the electrical protection installed at the terminal points of an electrical power line, and this requires a communication link between the two terminal stations of a line.

Teleprotection systems can be classified into two categories according to the type of information that is transmitted:

- analogue comparison systems;
- command systems.

Analogue comparison protection systems compare the amplitude and a phase of the electrical power system currents at each end of a line. The analogue signals are processed at each end of the power line and are compared with the local values to determine if there is a fault which is internal or external to the line section.

In command systems the information transmitted between the ends of a protected line consists of a change of state, OFF-ON or vice versa. There are three basic methods of using simple command signals in a protection system, namely to give a command "to trip" (intertripping scheme); to give an advisory command that permits tripping (permissive trip scheme); or to give a command to prevent tripping (blocking protection scheme).

In the intertripping mode the command can be used at the receiving end to effect the tripping without taking into account the local protection status (this is also known as direct or transfer tripping); in the permissive mode the command can take effect only if the local protection has operated. In the blocking mode the action is to prevent operation of the protection equipment for an external fault.

In each case command systems require that the teleprotection is fast, dependable and secure. However, these parameters are inter-dependent. (for a given bandwidth) and one can only be improved at the expense of the other(s). The requirements differ according to the type of system in use.

For a defined dependability and signal to noise ratio (S/N) in the transmission path, the maximum teleprotection transmission time for command systems, excluding propagation time, should be:

- less than 20 ms for blocking systems;
- less than 40 ms for permissive tripping systems;
- less than 60 ms for intertripping systems.

Note that power system stability and security considerations may require transmission times considerably less than the above, e.g. 20 ms for intertripping.

Dependability is the probability that the command is correctly received. It is given by 1-Pmc, where Pmc is the probability of a missing command. For the transmission times given above and a defined S/N ratio, the probability (Pmc) of a missing command should be:

- less than 10^{-3} for blocking systems;
- less than 10^{-2} to 10^{-3} for permissive tripping systems;
- less than 10^{-3} to 10^{-4} for intertripping systems.

Security is the probability that unwanted or incorrect commands do not occur. It is given by 1-Puc, where Puc is the probability of an unwanted command. For the transmission times given above and a defined S/N ratio, the probability (Puc) of an unwanted command should be:

- less than 10^{-1} to 10^{-2} for blocking systems;
- less than 10^{-3} to 10^{-4} for permissive tripping systems;
- less than 10^{-5} to 10^{-6} for intertripping systems.

The transmission of a protection command over an analogue transmission medium usually requires a channel bandwidth between 120 Hz and 480 Hz, but not exceeding 4 kHz.

Analogue comparison protection systems, on the other hand, require a security and dependability as high or higher than for the command systems, but require also good fidelity in the transmission of the analogue waveform. Moreover it is necessary that the communication channel should not distort the variations of the transmitted waveform. The transmission channel, therefore, is usually wider than for command protection systems and requires a whole 4 kHz channel in analogue transmission media and a bit rate of 19,2 kbits/s to 64 kbits/s or better in digital transmission media.

The operating time of an analogue comparison protection system is the time from the instant of fault inception to operation of the tripping output contact. This will be generally less than 60 ms although system stability and security considerations may require operating times considerably less than the above, e.g. less than 25 ms. In general the operating time will be increased by noise. The teleprotection transmission time, excluding propagation time, is normally kept small, e.g. less than 5 ms.

4.1.6 *Mobile radio*

Mobile radio provides a unique means of communication with personnel in the field for the operation, fault clearance, repair and construction of electricity networks and for the provision of an efficient consumer service. Its use contributes to the high reliability of the public electricity supply which is achieved today and it is indispensable for maintaining the availability of the supply.

There is no alternative to mobile radio for dispatching maintenance teams at very short notice and for coordinating their activities. Without mobile radio the outages on the electrical network would be two or three times longer in duration.

The traffic offered by the users of mobile radio networks of electric power companies is normally no higher than that offered by users of other private mobile radio networks of commercial or industrial companies. However, the traffic offered becomes much greater in emergency situations, such as during bad weather conditions (heavy rain, snow, wind, hurricanes, etc.) when failures and outages of the electrical power lines are more likely to occur. The dimensioning of the mobile radio networks has to be designed taking into account such conditions, so that the networks do not become overloaded or saturated just when they are most needed.

For large electric power system operation the following types of mobile communications are desirable:

a) person to person or mobile to mobile communications for short ranges (few kilometres) e.g. during line construction or line survey;

b) local area communications, base-mobile and/or mobile-mobile for ranges of a few tens of kilometres, such as the coverage of urban and suburban areas (the coverage might be achieved by a single base station or by a suitable repeater station);

c) wide area communications, base-mobile and/or mobile-mobile for ranges of many tens of kilometers in areas that require many base or repeater stations for the territory to be covered. Cellular mobile radio networks can often be used for wide area communication.

Type a) can utilise frequencies different from type b) in order to relieve the frequency congestion, e.g. UHF and VHF. Type c) normally requires microwave radio networks for connection between the base and repeater stations.

Such types of networks are very convenient permitting staff savings and operational coordination in an area corresponding to that telecontrolled by District Control Centres.

Given the traffic to be served and the shortage of suitable frequencies that occurs in most countries, it is very convenient to resort to networks of the cellular type, with cells of different sizes depending on the traffic density and on other technical considerations. In each cell a number of trunked channels are available for the users.

Another technique that can profitably be used, even with trunking, is the simultaneous broadcasting of which there are two types: synchronised carrier and quasi-synchronised carrier.

Most mobile communication networks provide voice communications and much of the time the service requires conferencing facilities and interconnection with the operational telephone network.

Conferencing is essential in emergency conditions for the coordination of the many teams that are required to operate simultaneously.

In addition to voice use, the operation of electrical networks today requires data transmission from or to mobile stations. The need is for coded messages, that can contribute to relief of the traffic on the networks by reducing the need for voice communication. The transmission of written messages is increasingly required in order to save time when written instructions or authorisations are to be exchanged for operations.

Once the mobile station is equipped for data transmission it is evident that the possibility exists of using mobile networks for telecontrol. As a matter of fact this is a facility that is often required, mainly in connection with MV electrical networks. Such a feature is very attractive, because it allows extension of the telecontrol networks without requiring expensive dedicated communication networks. Nevertheless data transmission over a mobile network requires that quality, reliability, availability, dependability and security standards should be similar to those achieved in fixed telecommunication networks.

The telecontrol and data transmission applications should not offer traffic values that impair voice communication, and they should be confined to services not requiring a permanent channel and offering very low traffic.

4.1.7 *Computing traffic*

For handling computing traffic either dedicated circuits or packet switched services are required.

Dedicated circuits are advisable where line utilisation is very high although they do not permit ready access to alternative routes if the direct route fails nor is routing to more than one address very efficient.

Packet switching is particularly suited to larger data networks where the main data routes can be trunked and where multi-access use is required for relatively low data throughput by the user.

4.1.8 *Other Services*

Teleprinting, facsimile, and electronic mail

In addition to the telephone network and the facilities for overall system control, electrical utilities also need teleprinting and facsimile facilities, not only for general and administrative services, but as an important aid to the operation of the electrical network.

Teleprinters are normally operated as simple point-to-point links, so that they are continuously available to the users. Nevertheless in very big networks, where a large number of users have to communicate with one another the teleprinting system can make use of message switching exchanges, like a telephone network, even though direct circuits are always reserved for the main network nodes and control centres.

Teleprinting is required for transmitting important information associated with operations, e.g. instructions for and confirmation of extraordinary switching states under emergency conditions, or in connection with maintenance and repairs on the electrical network.

For teleprinting, dedicated channels are normally used, with bit rates between 50 bits/s and 4 800 bits/s. The higher bit rates are reserved for the more evolutionary teletex applications.

Facsimile is more and more widely used by reason of its immediacy for the transmission of document copies, drawings and graphics and utilises the telephone network and telephone extensions.

If facsimile is used directly for operations the operational telephone system is generally used as the communication media. If facsimile is required for administrative purposes the operational telephone system may also be used, if permitted by the PTT, otherwise the public telephone network is used.

Electronic mail, which is based on the storage and forwarding of messages, may also be used in place of or as well as teleprinting for administration traffic. With electronic mail a "mail-box" is used requiring the recipient to access his own mail-box to read messages destined for him. Electronic mail makes use of VDU terminals.

4.2 *Electro-magnetic compatibility (EMC)*

The first problem that arises when dealing with telecommunication links having at least one of its ends terminated in an electrical station is the rise in the earth potential as a result of a conductor of an electrical HV circuit or a station busbar being temporarily connected to earth (short circuit fault). For a few tens of milliseconds, until the fault is disconnected by operation of a circuit breaker(s), the potential of the local earth can be very different from the potential of the remote earth. If a metallic telecommunication circuit is used which connects the station with another site it will be subjected to a common-mode voltage that is applied to the input/output of the terminal equipment and can cause damage to the equipment and/or danger to personnel.

Moreover, due to unbalance in the telecommunication circuit the common mode voltages can result in differential mode voltages which can cause serious damage to telecommunication equipment.

The second problem is that of overvoltage due to lightning and other electrical discharges when opening circuit breakers and isolators. Lightning can reach the telecommunication equipment via power supplies, communication circuits, and aerial towers. Lightning can also raise the local earth potential causing impulsive voltages at the input/output of telecommunication equipment.

Further problems can arise from induction due to the passage of load or fault currents in electrical power lines and station busbars.

In facing all the above problems, which are typical for equipment installed in electrical plants, power stations and substations, it is necessary to make use of equipment that ensures both damage limitation (i.e. the capability of the equipment not to be damaged) and immunity (i.e. the capability to perform its operational characteristics without any disturbance). Furthermore, no radiation or other disturbances should be emitted which could disturb other equipment.

Depending on the site and on the electrical environment, some or all of the following requirements shall be taken into account (but see the relevant IEC documents and/or publications for details):

- minimum insulation resistance to earth (10 MΩ to 100 MΩ);
- electrical insulation withstand (1 kV to 2 kV, a.c. or 1 kV to 3 kV, d.c.) for 1 min;
- impulse withstand (1 kV to 5 kV; 1,2/50 µs; higher values may also apply in certain circumstances, e.g. 6 kV or more, 0,1/2 000 µs);
- immunity to current impulses (up to 500 A; 8/20 µs);
- immunity to voltage impulses (2 kV; 10/700 µs);
- immunity to short supply interruptions (10 ms to 500 ms);
- immunity to distorted a.c. power supply voltage (up to 15 %);

- immunity to residual a.c. on d.c. power supply (0,2 Vpp to 15 Vpp; 100 Hz);
- immunity to a.c. and d.c. voltages (10 V to 250 V) on signal inputs (metallic);
- immunity to trains of sinusoidal oscillations on supply inputs (20 ms; 0,01 MHz to 1 MHz; 10 V to 100 V);
- immunity to damped sinusoidal oscillations on signal inputs (0,1 MHz to 1 MHz; 0,2 kV to 2,5 kV);
- immunity to static energy discharge (5/30 ns; 2 kV to 15 kV);
- immunity to 50 Hz magnetic field (1 s; 0,1 kA/m to 1 kA/m);
- immunity to impulsive magnetic field (8/20 µs; 0,1 kA to 1 kA);
- immunity to damped magnetic field (0,1 MHz to 1 MHz; 10 A/m to 100 A/m);
- immunity to radiated electromagnetic field (continuous and modulated field, 10 V/m or more within the frequency range 100 kHz to 1 GHz). For example, from a hand-held "walkie-talkie";
- immunity from switching transients up to 300 V/m.

Apart from d.c. supply inputs and RF connections to antennae, it is desirable that all the other inputs/outputs be balanced and insulated from ground.

When circuit breakers or isolators open, they generate electrical discharges producing very high noise levels in the telecommunication circuits. The noise power can easily exceed the level of signals transmitted by power line carrier systems, so that during the discharges transmission may be lost, unless very careful signal processing is applied.

Electrical discharges also generate radiation of electromagnetic waves having quite a broad spectrum. Among the causes of electromagnetic radiated noise are micro-discharges on faulty insulators or insulators with dirty surfaces or in other electrical devices.

All these circumstances mean that careful attention has to be observed when operating radio-receivers working at LF, MF, HF and the low bands of VHF by ensuring that the received field values are higher than usual practice. At 160 MHz, for example, noise figure impairments of some decibels have been measured in the areas occupied by electrical stations. These impairments, which have a power spectrum density decreasing with frequency, can be neglected for UHF and microwaves.

4.3 *Other requirements*

In the foregoing subclauses we have seen that electric power systems need telecommunication networks that are very reliable and always available. Reliability and availability cannot be ensured simply by providing alternative signal routing and path redundancy. They require also high reliability and availability on each path, so that the dependability required by the services is ensured even in the case of failure of one of the paths. Moreover, if the transmission performance of each path is not good enough the signal received at each end of a link, obtained by selection or combination, may be affected by phase jitter that can considerably impair data transmission and telecontrol.

Another requirement concerns response times. The response times should be short and stable. Attention should also be paid to timing and synchronisation problems when digital transmission systems are used.

Telecommunication networks for power systems also have to be flexible. The many changes required as the power network parameters and configuration alter make it desirable that the telecommunication network be capable of adapting to the different situations. Standardisation, upwards capability, spare bandwidth and spare channels are some of the necessary features of the telecommunication network.

A noticeable improvement to the network flexibility can be achieved in digital networks by resorting to programmable and teleprogrammable multiplex equipment capable of switching their channel input/outputs to different time-slots. Also programmable drop-insert and branching equipment should be employed for similar reasons. All these features should be provided by a suitable telecommunication network management system.

From the above considerations it appears that electric power utilities need very special telecommunication networks, having characteristics that usually cannot be provided by public networks, as these are designed and optimised for other services and other requirements. In fact, for the very demanding operational applications of generation and transmission, the most developed electric power utilities are always served by dedicated networks.

If one considers emergency conditions such as natural disasters, floods, blizzards or earthquakes requiring the maintenance and rapid restoration of public electricity supply, an electric utility cannot relay on systems shared with other services and utilities which may themselves be overloaded by reason of the same emergency conditions.

It has already been said that just as telecommunication networks for power utilities should be designed and equipped in order to serve the traffic foreseen in emergency conditions, so these same circumstances shall also be taken into account when choosing the various transmission media.

As an example it is evident that the availability of a PLC channel is correlated with the availability of the electrical overhead line on which it works, so that PLC should only be used on peripheral telecommunication services, as it may not be the best choice for long range communications, requiring many sections in cascade. Similarly, where the availability has to be independent of the availability of electrical overhead lines, PLC should not be used.

This argument is applicable also to telecommunication systems based on optical fibre cables supported on overhead electrical lines. The availability of a optical fibre link depends on the availability and mean time to repair (MTTR) of the electrical overhead lines on which it works.

Thus when using PLC or fibre-optics on power lines it is advisable to provide redundancy of different paths and it is also desirable that at least one of the paths be provided by an alternative media such as radio links.

This last point is important also in relation to economic considerations. In fact the capacity normally required for electric utilities means that it may be cheaper to use radio links, which can also be used for interconnecting repeater stations to provide suitable mobile radio system networks.

A further point concerns the power supplies required by the telecommunication services. Low voltage (e.g. 48 V d.c.) supplies require battery back-up of normally six hours capacity. Main a.c. supplies will require uninterrupted power supplies backed up by diesel-alternators with fuel tank storage of many days capacity.

All these considerations make it imperative to use the services of professional specialist support in designing the telecommunication services of an electrical power utility.

5 Impact on telecommunication provision

5.1 *Transmission media*

This subclause is not intended to give a detailed description of the transmission media available for use by an electrical power utility but highlights those aspects considered to be important. The international standards (IEC, CCITT, CCIR, etc.) give all the detailed information that may be required.

Figure 10 indicates the various telecommunication transmission media that may be available to the user for conveying information from one point to another.

There are several criteria that have to be observed in selecting a particular transmission medium. These criteria are:

- How many channels are required?
- What is the required transmission capacity for each channel?
- What constraints are there? For example: geographical, regulatory, distances, frequencies available for use, terrorist activity, power supplies;
- What are the required reliability and quality for the system?

5.1.1 *Pilot cables owned by the utility*

Electrical power utilities frequently make use of their own pilot cable for protection and telecommunication services. These cables are usually run underground in cable trenches and are frequently laid in the same trenches as HV cables. Because of this, great care needs to be taken in handling pilot cables due to the presence of induction from the HV cables, especially when there is a power system fault.

Care also needs to be taken to ensure that the electrical balance of the cables is sufficient so that induction from HV cables does not make the communication media unusable.

For telecommunication purpose, cables having balanced, twisted pairs should be used. These cables can be protected by such devices as isolating or neutralising transformers, with non-linear devices (e.g. carbon blocks or gas tubes) to limit dangerous voltages, although the use of these on circuits used for teleprotection may be undesirable (see figure 11). In order to reduce the induced voltage the cable may be sectionalised by intermediate isolating transformers. The attenuation of the pilots may be quite high and usually only audio frequencies up to say 4 kHz, are usable. Hence distances over which such cables may be used without amplification may be limited to 10 km to 15 km.

5.1.2 *Circuits leased from PTT's*

Telecommunication circuits may be leased from the PTT for an annual rental charge and an initial connection fee. Analogue and digital circuits may be hired to provide audio (300 Hz to 3 400 Hz) or 64 kbits/s channels respectively. Wider bandwidths are available to provide more channels, for example 12 channels in the range 60 kHz to 108 kHz (FDM) or 30 channels at 2,048 Mbits/s or 24 channels at 1,544 Mbits/s (TDM/PCM).

The PTT may well impose certain restrictions on the use of their circuits particularly where circuits have to enter HV premises. Isolation transformers will be necessary as well as non-linear devices to limit dangerous voltages, although the use of these on circuits used for teleprotection may be undesirable. Where d.c. teleprotection circuits are required, neutralising transformers can be used to cancel the earth potential rise (EPR) and the induced voltages in metallic cables.

5.1.3 *Power line carrier (PLC)*

a) *Principle*

The electricity industries are unique in that they have available to them very reliable physical paths, i.e. the transmission power lines which interconnect the points of generation and load and over which telecommunication signals can be transmitted. Since the high-voltage transmission line is used as the communication medium, it is not possible to transmit the useful audio frequency band directly, because the frequencies in this band are too close to power system frequency and hence it is necessary to translate the audio band by suitable modulation to occupy a different part of the spectrum. For this power line carrier equipment has been specifically designed for use on a power network. PLC permits, by high frequency SSB (Single Side Band) modulation, the transmission of analogue information. Although primarily intended to utilise overhead transmission power lines, PLC can also be used for communication over:

- submarine or underground power cables;
- cable incorporated into ground wires (coaxial or quadded cables).

b) *PLC frequencies*

The range of frequencies suitable for conventional power line carrier transmission extends from about 30 kHz to 500 kHz (in some countries 490 kHz), the lower limit being fixed by the limitations and cost of the coupling equipment, and the upper limit by line attenuation and radiation. The actual range of frequencies available for use in a particular country should take into account the needs of various radio services and broadcasting services, including aeronautical and maritime navigation systems together with any local or national restrictions or regulations.

c) *Applications*

Any audio frequency channel of up to 4 kHz bandwidth (in some countries 2,5 kHz) is available and can be used to carry:

- either analogue information in the form of speech, or
- speech plus data (S + D), the data consisting of telemetering, telecontrol, teleprotection, data, etc.

d) *Noise and permissible signal to noise ratio*

Power line carrier links are subject to two main types of noise:

i) Sustained white noise-like voltages (random noise) caused by irregular electrical discharges across insulators and conductors (corona or brush discharge).

ii) Short spikes and bursts of high amplitude caused by operation of isolators and breakers or by lightning, flashovers and the like.

These noise levels determine the PLC link quality. The permissible signal to noise ratio limit is defined in IEC 663.

e) *PLC offers:*

- long range on a single link (several hundred kilometers without repeater depending on the transmitter power and frequency);
- very high equipment availability;
- very high equipment reliability.

In spite of the many advantages, there are some limitations:

- narrow AF bandwidth and hence very low number of channels;
- narrow available HF spectrum;
- attenuation increase due to use of HV line transpositions;

- dependence on electrical line availability.

5.1.4 *Fixed link radio*

This subclause is intended to cover fixed radio links: microwave and UHF.

a) *Main features*

Radio links are widely used to provide power system telecommunication services for the following reasons

- galvanic isolation;
- independence from power lines;

- large number of circuits;
- low cost in comparison with other media;
- additional services can be provided relatively easily and at low cost;
- easy maintenance (the equipments are located at a few sites only);
- high quality and high reliability.

However there are fundamental difficulties in the provision of radio links i.e.:

- obtaining suitable frequency assignments;
- propagation problems depending on frequency and fading (non-total availability during adverse weather);
- repeater cost and need for power supplies;
- difficulties in linking low altitude stations.

b) *Design considerations*

The first stage is to determine the exact locations which are to be interconnected and the necessary transmission capacity. This first approach will then determine the appropriate frequency range. The radio path loss budget can be determined by calculation of:

- free space loss;
- additional losses in the form of fading, sometimes deep (obstacles, variation in refractive index of the atmosphere, absorption, multipath reflections, etc.);
- interference calculations.

Then, all the necessary equipments can be defined as follows:

- terminal equipment;
- repeater equipment;
- type of wave guide feeder;
- type of antennae;
- height of towers.

An example of typical radio link is given in figure 12.

c) *Frequencies available*

Frequency assignments are generally made by the national frequency administration. Information is provided in ITU and CCIR publications.

5.1.5 *Mobile radio*

Mobile radio makes use of VHF (70 MHz to 165 MHz band) and UHF (400 MHz to 470 MHz band) using AM or FM (PM).

At its simplest, mobile radio in the VHF band consists of a base station usually located at as high a point as possible and a number of mobile units, each equipped with transceivers.

5.1.6 *Fibre optics*

An optical fibre link is characterised by the following main properties:

- very wide bandwidth;
- very low attenuation;
- immunity to electromagnetic interference;
- low weight and small cable size;
- reliability unknown but likely to be good;
- high cost in comparison with other media;
- high transmission quality.

Thus, this transmission medium is suitable for transmission of many simultaneous channels by means of time division multiplexing.

For this purpose, the design is obtained by loss budget and bandwidth budget calculations which permit determination of:

- type of optical fibre (multimode or single mode fibres);
- type of light transmitter (LASER diode or LED);
- type of light receiver;
- ancillary equipment (repeater, etc);
- available bandwidth.

An example of a typical optical fibre link is given in figure 13.

5.1.7 *Satellite systems*

Where the territory to be covered is large, consideration should be given to using the facilities provided by satellite systems. Each outstation and the control centre would require an earth station equipped with a suitable aerial. Unfortunately the cost of such systems is high and also requires hiring of the satellite service from a carrier as the user does not own the facility. TDM systems operate over satellites, hence many of the attributes of optical fibre and fixed link radio also apply (e.g. many channels of high quality with good S/N).

5.2 *Multiplex equipment*

In order to make effective use of the transmission medium, it is necessary to carry simultaneously more than one audio frequency channel. This can be realised by analogue (FDM) or digital (TDM) multiplexing techniques. The CCITT have laid down a number of recommendations for such systems.

a) *Frequency division multiplex, FDM*

With this method a number of audio channels are translated to occupy discrete positions in a frequency domain covering a wide frequency band.

Each audio channel, including a signalling frequency of 3 825 Hz, occupies a bandwidth of 4 kHz. The translation is made in successive steps, first by combining into primary groups of 12 channels (bandwidth 60 kHz to 108 kHz) then into supergroups of 60 channels (bandwidth 60 kHz to 300 kHz) and so on.

b) *Time division multiplex, TDM*

With this method a number of audio channels are digitised and then translated to occupy discrete positions in the time domain.

The audio channels are sequentially sampled at a rate of 8 000 times per second. The pulse amplitude sample taken for each channel corresponds to the amplitude of the complex wave-form at the instant of sampling. The pulse amplitude is then coded into an 8 bit binary code and is allocated a time slot within the multiplexed signal. Thus an audio channel produces a digital signal of 64 kbits/s.

For 30 channel PCM, a basic frame of 2,048 Mbits/s is composed of a time-frame of pulses representing 30 telephony channels plus two channels reserved for signalling and synchronisation (32 x 64 = 2,048 Mbits/s).

This basic frame can be multiplexed with other frames to increase the transmission bit-rate (8; 34 Mbits/s, etc.).

Alternatively, for 24 channel PCM a basic frame of 1,544 Mbits/s is composed of a time-frame of pulses representing 24 telephony channels with an additional synchronisation bit for every frame ([8 x 24 + 1] x 8 = 1,544 Mbits/s). This basic frame can be multiplexed with other frames to increase the transmission bit-rate (6; 32 Mbits/s, etc).

c) *Applications*

This equipment is suitable for the following types of telecommunication link:

- microwave;
- coaxial;
- optical fibre (TDM preferably);
- satellite services.

Electrical public utility

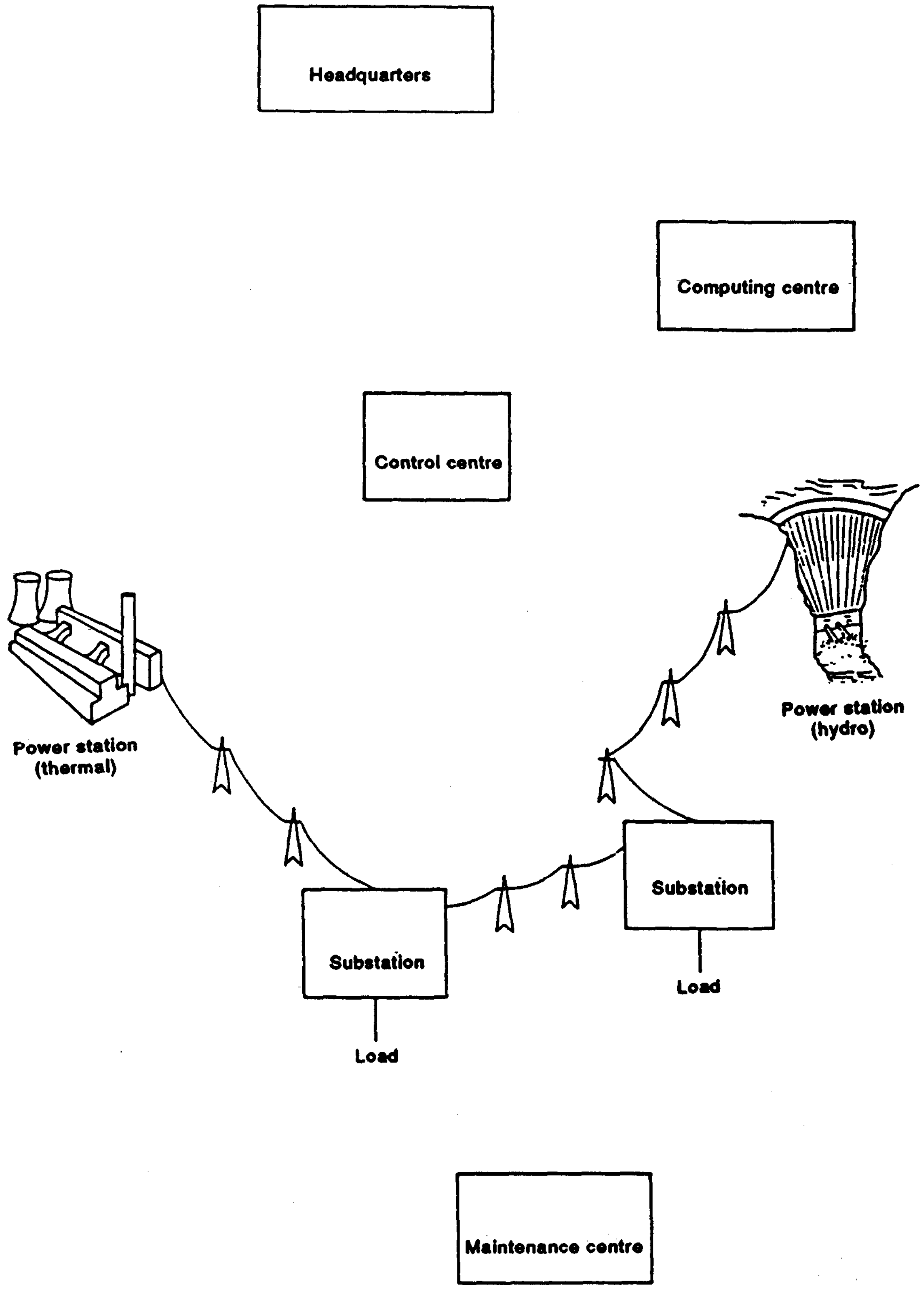


Figure 1

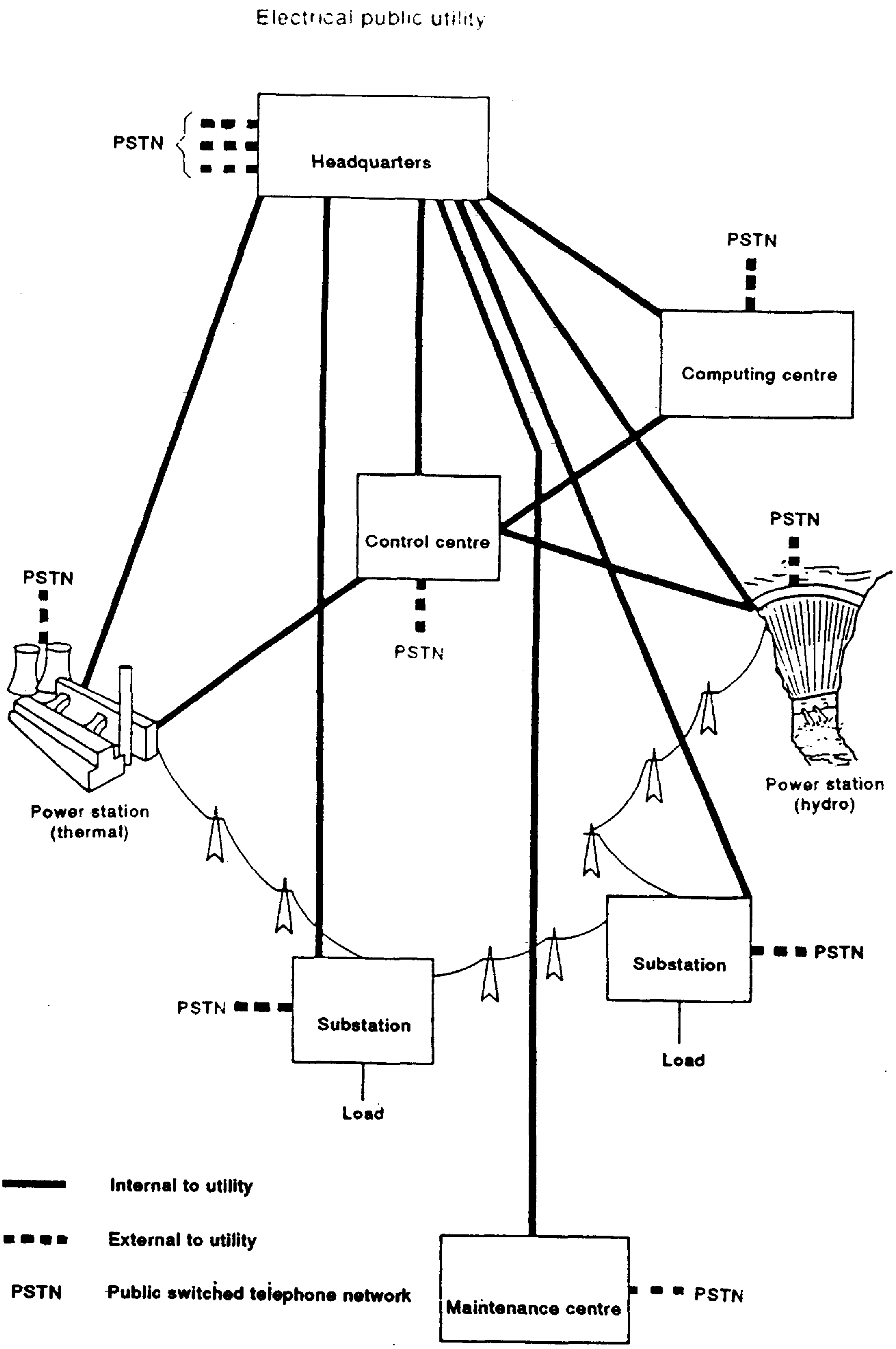


Figure 2 - Administrative telephone service

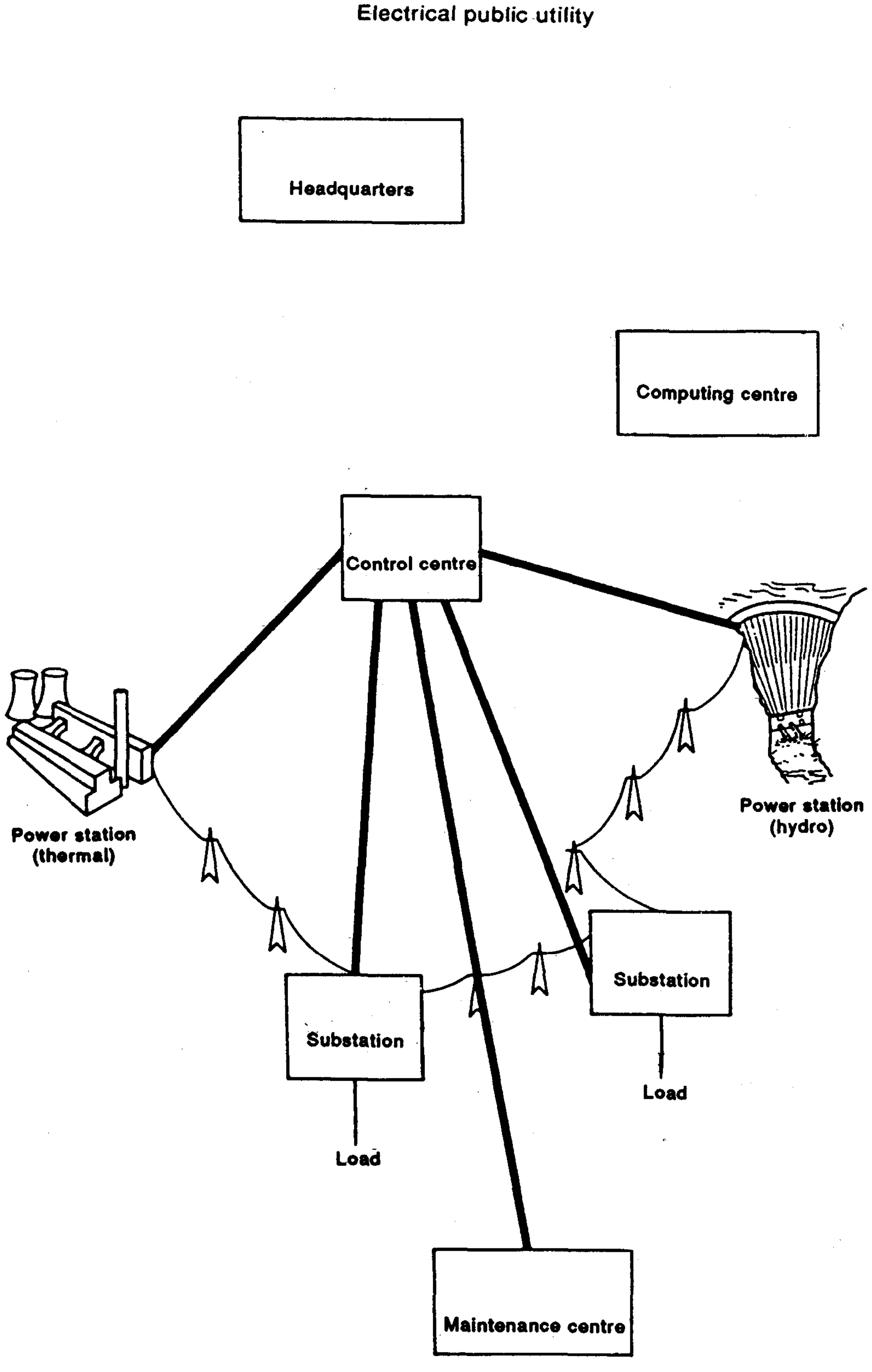


Figure 3 - Operational telephony

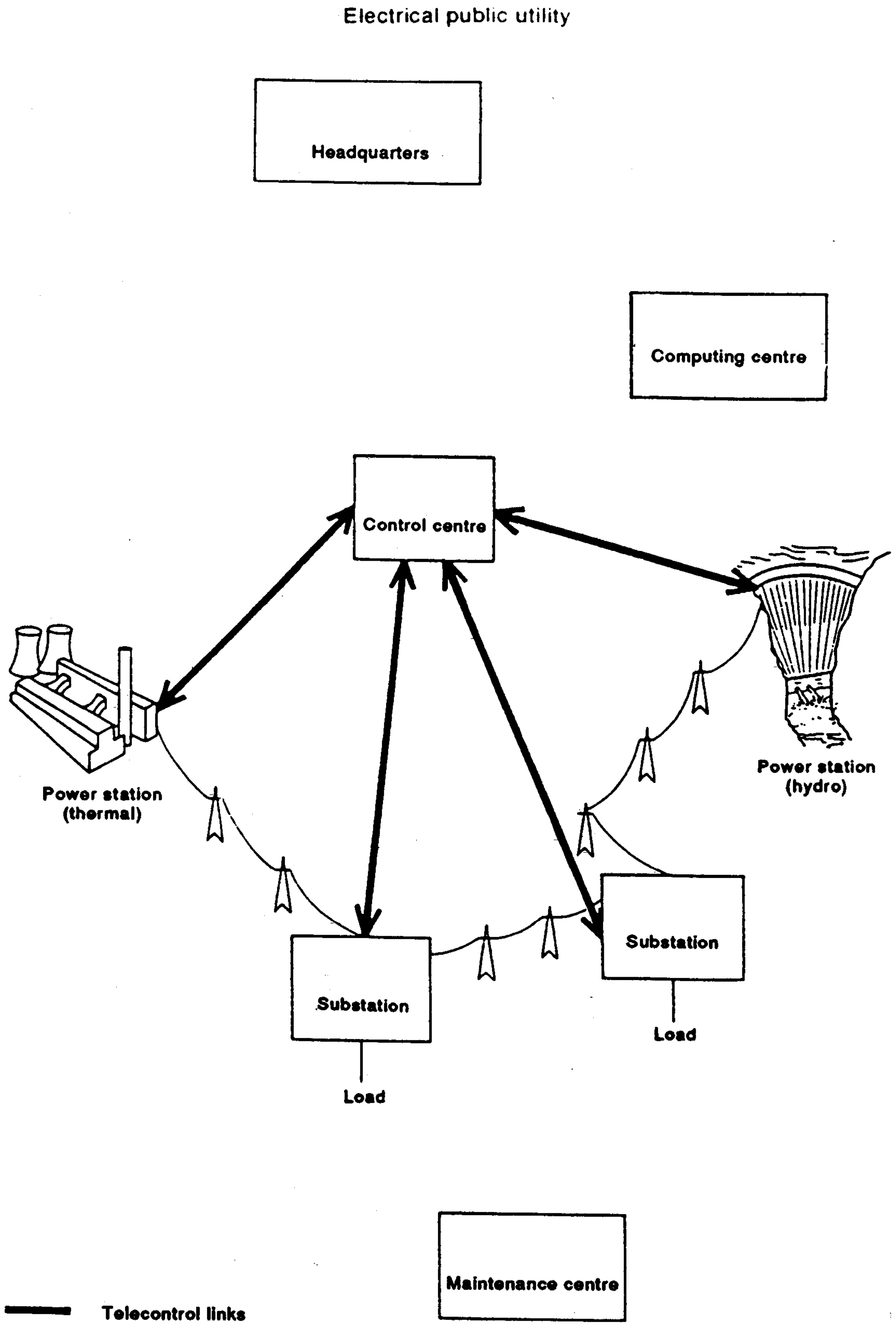


Figure 4 - Telecontrol

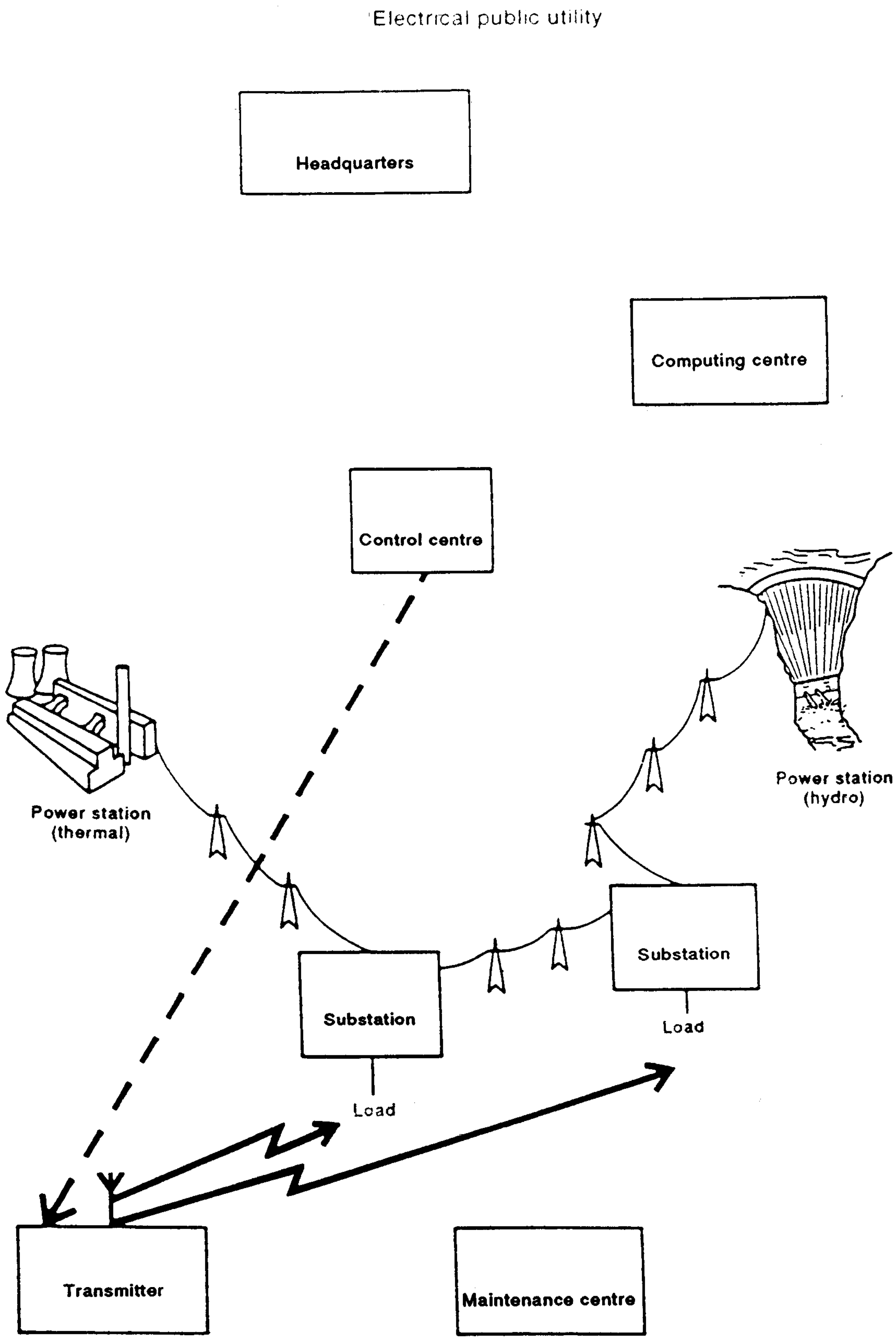


Figure 5 - Load management

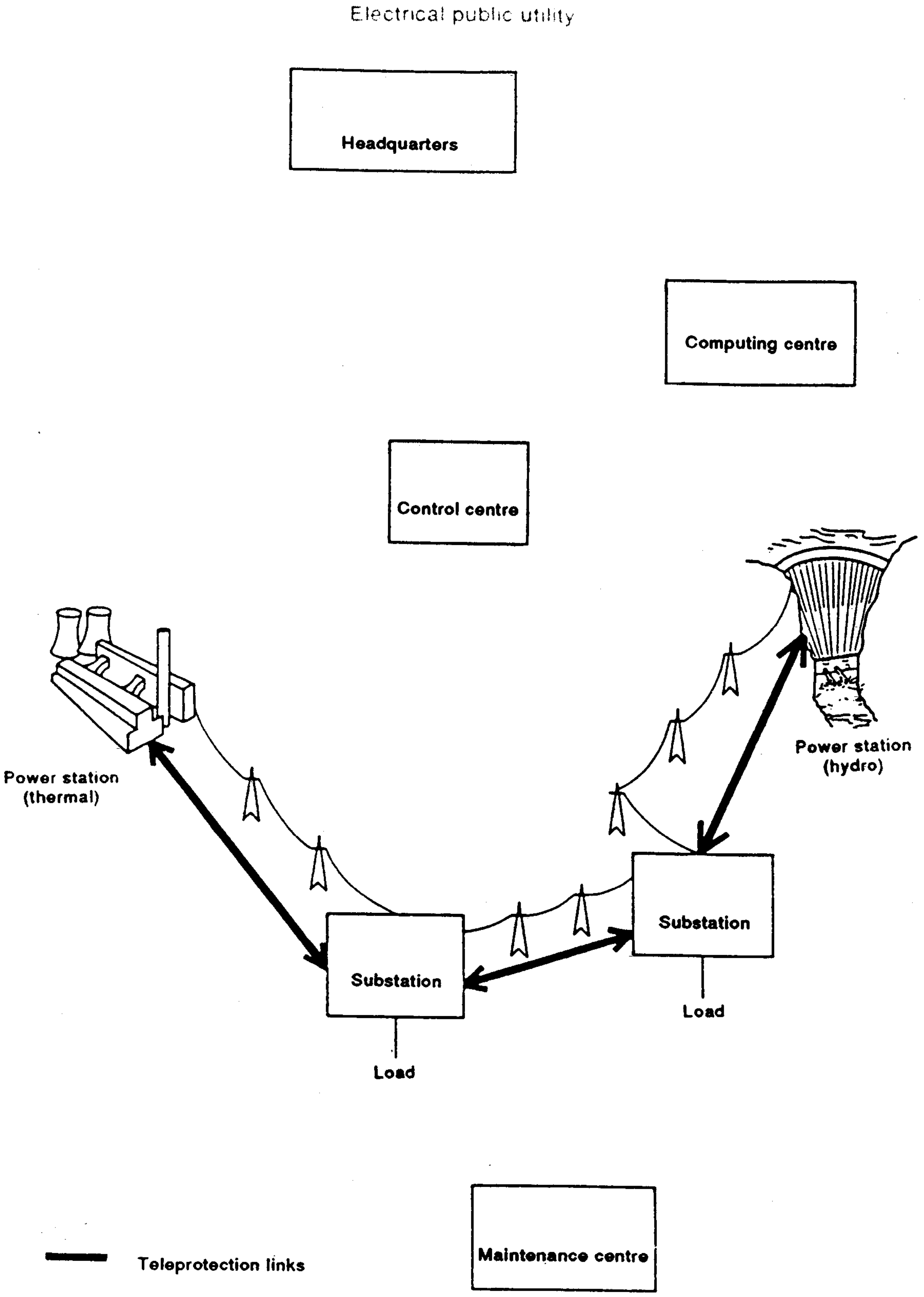


Figure 6 - Teleprotection

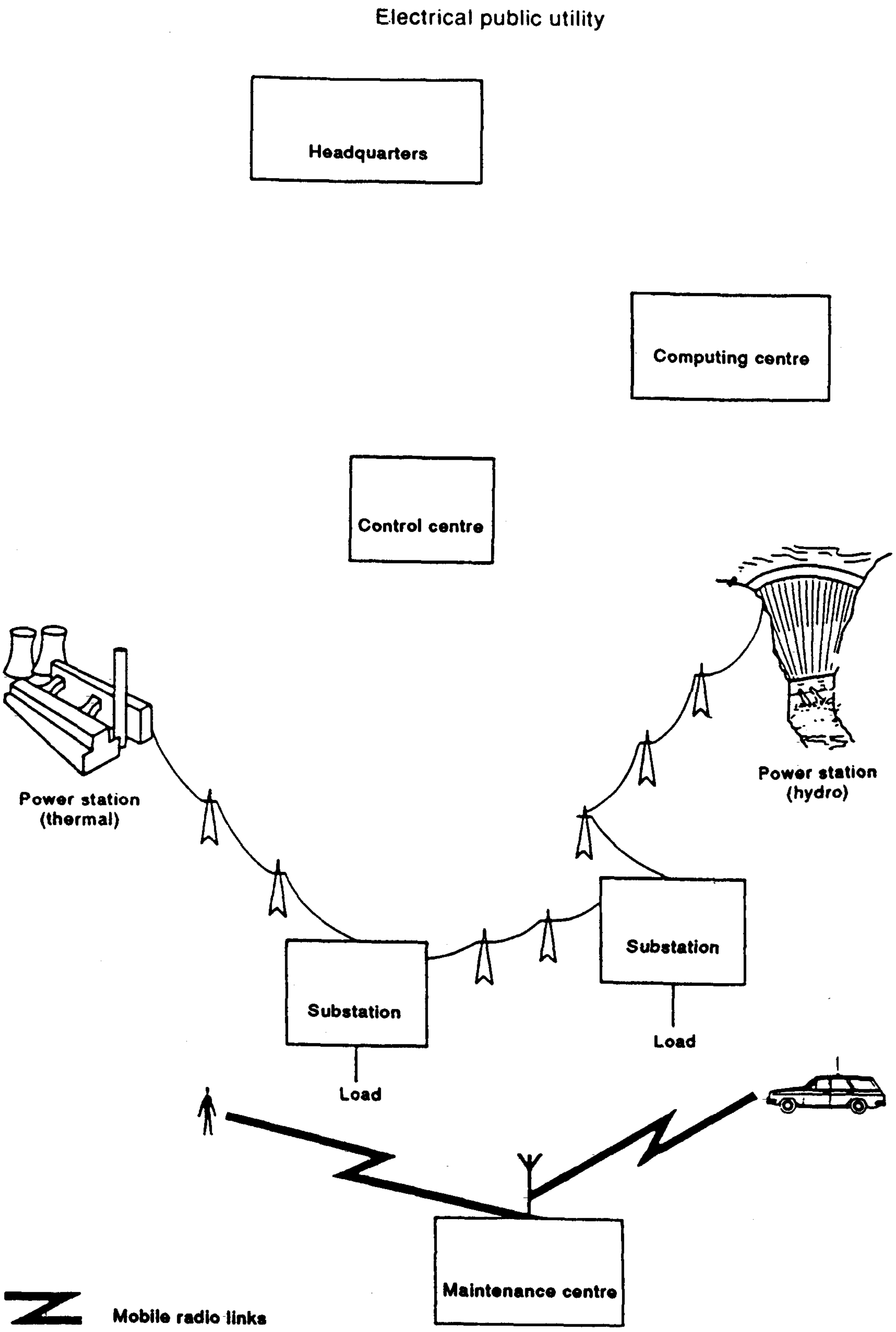


Figure 7 - Mobile radio

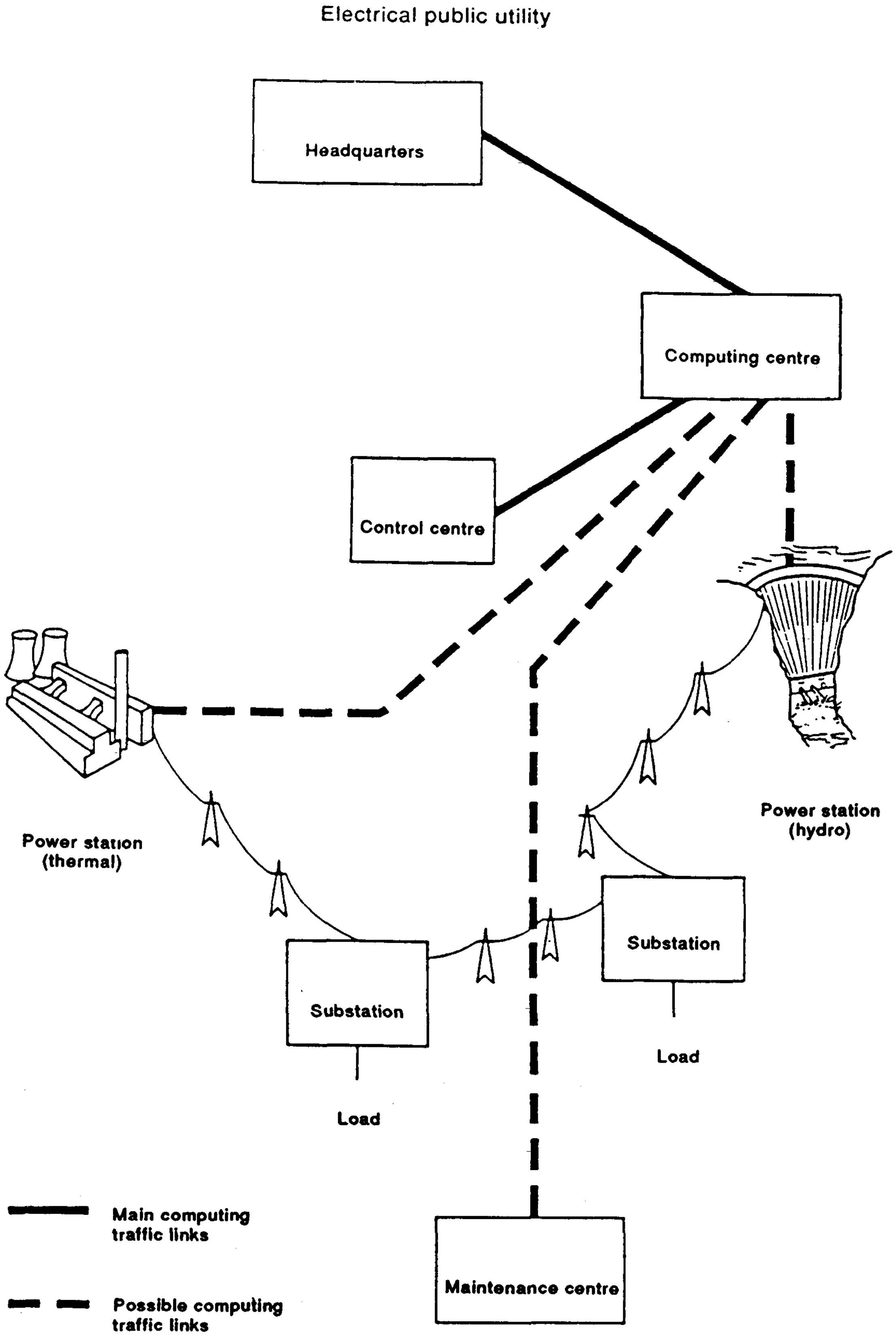


Figure 8 - Computing trafic

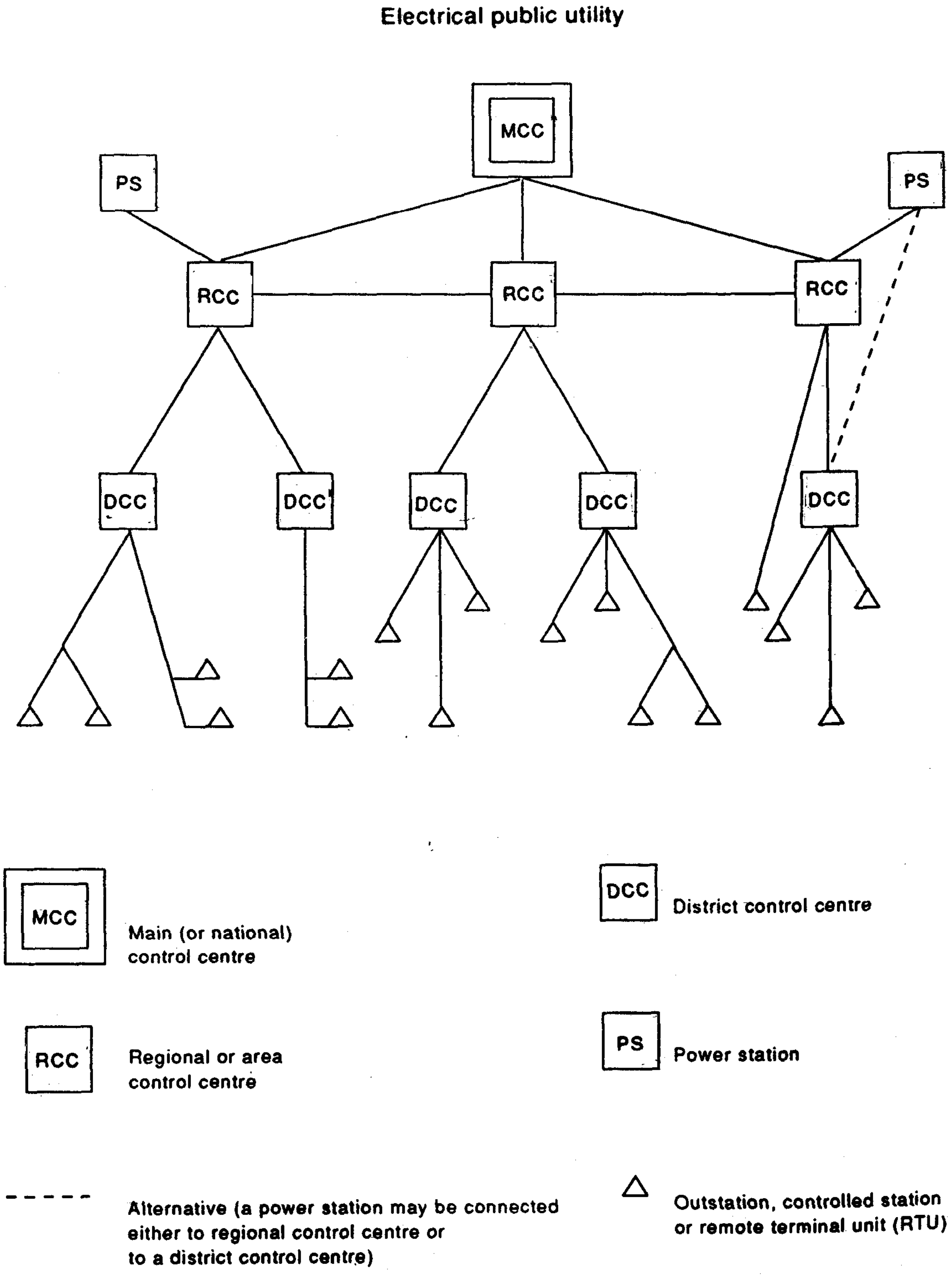

Electrical public utility
MCC
PS
PS
RCC
RCC
RCC
DCC
DCC
DCC
DCC
DCC
MCC
Main (or national) control centre
RCC
Regional or area control centre
Alternative (a power station may be connected either to regional control centre or to a district control centre)
DCC
District control centre
PS
Power station
Outstation, controlled station or remote terminal unit (RTU)

Figure 9 - Typical hierarchical structure of a telecontrol system

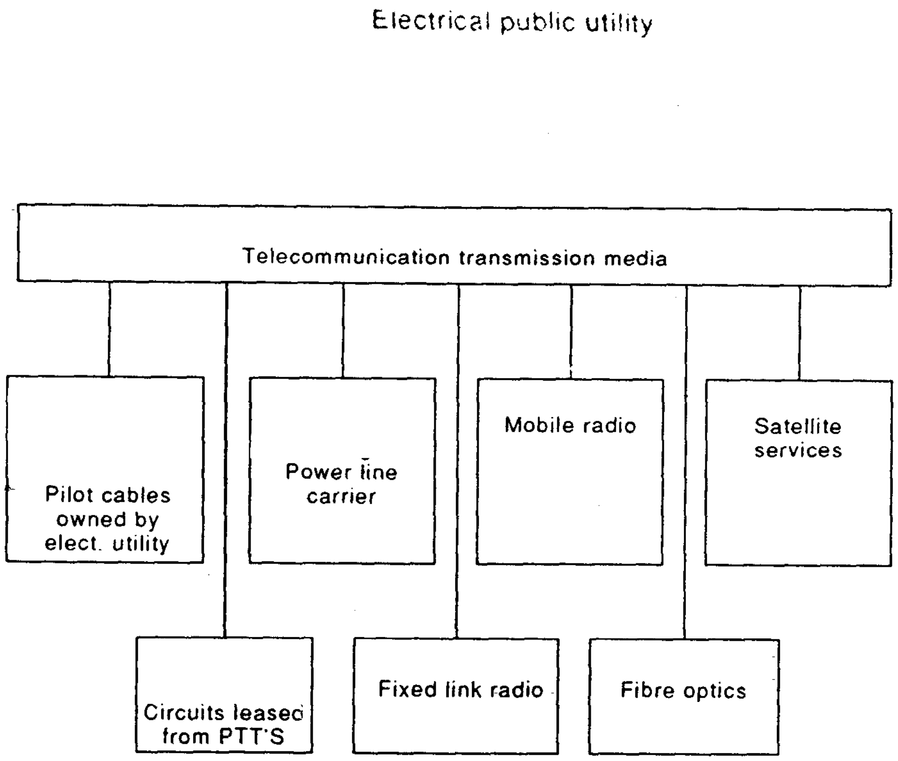
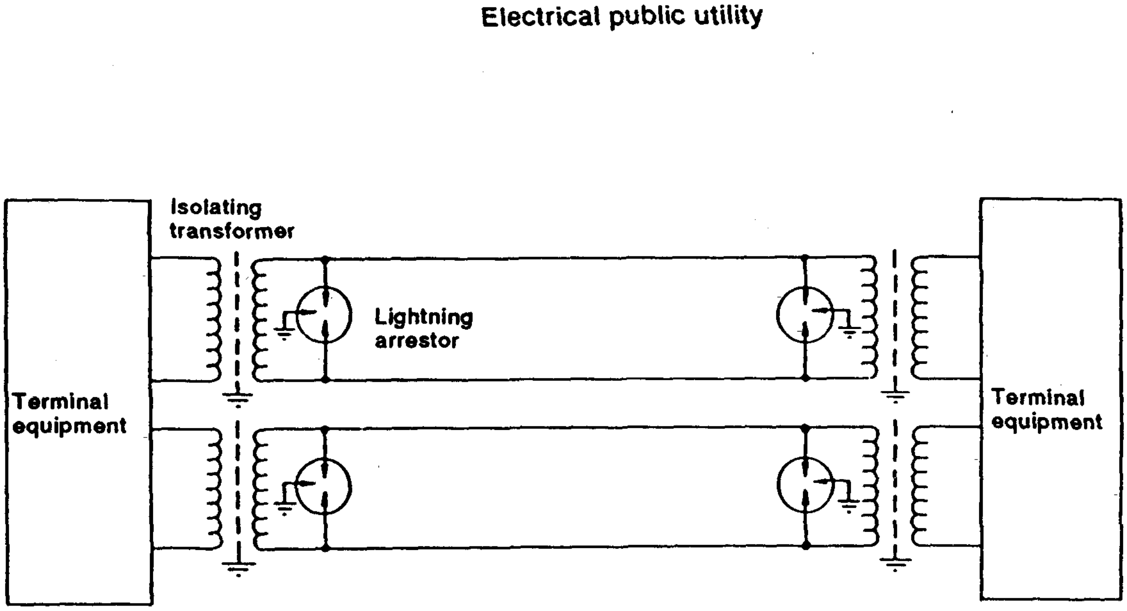

Electrical public utility
Telecommunication transmission media
Pilot cables owned by elect. utility
Power line carrier
Mobile radio
Satellite services
Circuits leased from PTT'S
Fixed link radio
Fibre optics

Figure 10



NOTES

1 Isolating transformers having fully floating primary and secondary windings do not employ an inter-winding shield.

2 Neutralising transformers can also be employed as protective devices in certain situations.

Figure 11 - Example of use of audio frequency pilot cables

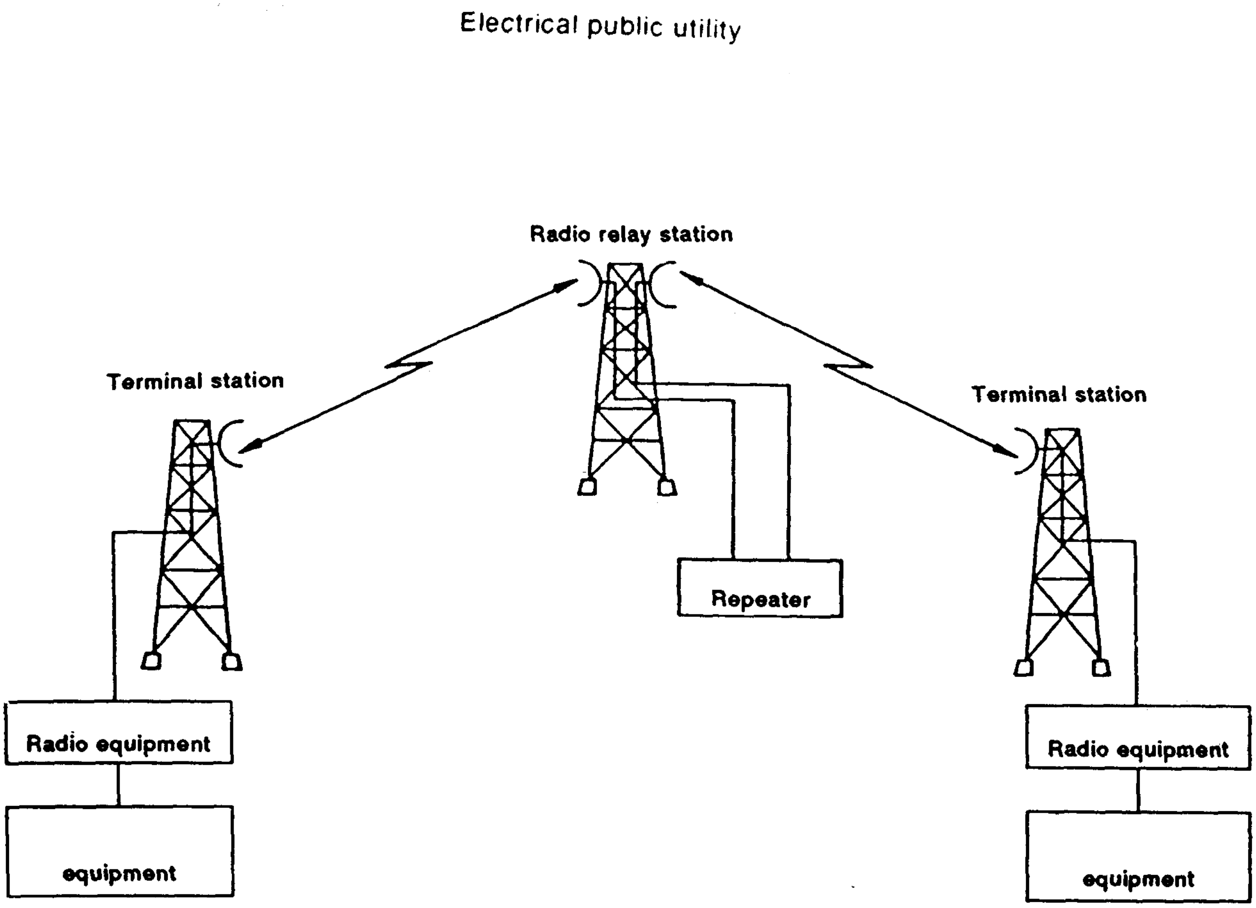


Figure 12 - Example of radio link

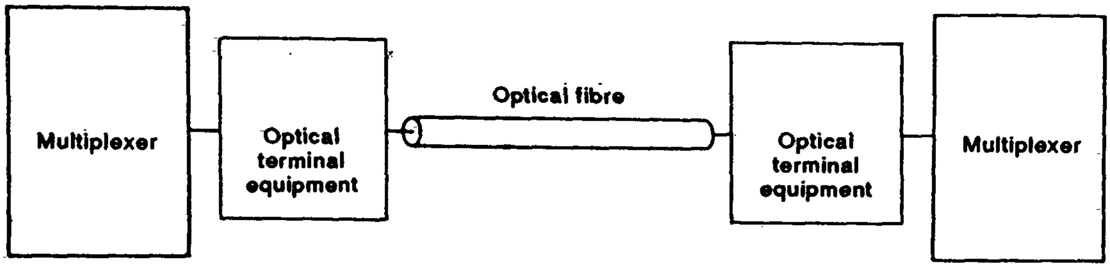


Figure 13 - Example of optical fibre link

(Continued from second cover)

IEC 481 (1974) Coupling devices for power line carrier terminals	IS 8997 : 1978 Coupling devices for PLC systems	Technically Equivalent
IEC 495 (1974) Recommended values for characteristic input and output quantities of single sideband power line carrier terminals	IS 9482 : 1980 Characteristic values of inputs and outputs of single sideband PLC terminals	Technically equivalent
IEC 663 (1980) Planning of (single sideband) power line carrier systems	IS 9528 (Part 2) : 1980 Manual for planning of (SSB) PLC systems : Part 2 PLC systems planning	Technically equivalent

The concerned technical committee has reviewed the provisions of IEC 870-6 'Telecontrol equipment and systems — Part 6 : Telecontrol protocols compatible with ISO and CCITT standards' (under consideration), referred in this adopted standard and has decided that it is acceptable for use in conjunction with this standard.

Only the English language text in the International Standard has been retained while adopting it in this Indian Standard.

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